CONCERNING THE GEOGRAPHIC DISTRIBUTION OF THE YELLOW FEVER MOSQUITO.

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The proper consideration of this now all-important species must necessarily be divided into two sections; first, the actual present distribution of the species so far as it can be ascertained; second, the exact limitations of the regions in which, if accidentally introduced, it may reasonably be expected to propagate and to become perfectly established. For immediate quarantine purposes the first of these is the most important, but looking to the future, an exact knowledge of the regions which must be included in the second category is obviously scarcely less important.

1. The present known distribution of the species.

When Mr. F. V. Theobald published his two volumes, A Monograph of the Culicidæ of the World, in 1901, he stated roughly that *Stegomyia fasciata*, which at that time was not known to him as the "yellow fever" mosquito, ranged from 38° south latitude to 38° north latitude, and his map upon page 292, Volume I, indicated a general distribution throughout eastern Australia, western Sumatra, all of Java and Farther India, southern Japan, eastern Hindostan, the Seychelles, southeastern Africa, the African west coast, including Senegambia and the District Lagos, all of Spain, southern Italy, the east coast of South America from British Guiana to Rio de la Plata, all of Cuba, Jamaica, Haiti, and all of the southern United States. In Volume III of this important monograph, published in 1903, the same author includes the following under "New localities:" St. Kitts, Nevis, Antigua, Carriacou (Grenadine Islands), Trinidad (Hewlett), Barbados, Dominica, Montserrat (Low), Luzon, Philippine Islands (September 7, 1901, Miss C. S. Ludlow); Port Darwin, South Australia; Para (Durham); Gambia (Burdett), taken in houses, McCarthy Islands, in July; Victoria, Seychelles (Denman); Nigeria (Hanley);

Fiji (Hewlett). Elsewhere he adds: Tyre and Sidon, Palestine; old Calabar; Mashonaland; Malay Peninsula and eastern Archipelago; Argentina, South America.

In my book on mosquitoes, published in 1901, I gave the then known distribution in the United States, as follows:

> In the United States it is common in most of our Southern States. I have seen specimens from New Orleans, La.; Natchitoches, La.; and Napoleonville, La.; eastern Texas; Hot Springs, Ark.; Pelham, Ga.; Virginia Beach, Va.

Since that time many new localities have been discovered, and our present knowledge of the exact localities may be tabulated as follows (those from without the United States being our own records additional to those of Theobald):

UNITED STATES.— *Virginia:* Virginia Beach. *Kentucky:* Lexington. *Illinois:* Cairo. *Tennessee:* Nashville. *Arkansas:* Hot Springs. *Louisiana:* Ruddock, New Orleans, Baton Rouge, Napoleonville, Hammond, Shreveport, Franklin. *Mississippi:* Pass Christian, Summit, Quarantine Station, Biloxi. *Georgia:* Atlanta, Pelham, Augusta, Savannah, Brunswick. *Florida:* Barrancas, Key West. *Texas:* Galveston, Houston, Victoria, San Diego, Tyler. *South Carolina:* Charleston, Sullivans Island. *California:* San Diego, Angel Island (Carter). *Maryland:* Baltimore (Carter)—breeding in fresh water on fruit wharf. *North Carolina:* Beaufort, Winston.

MEXICO.—Tampico, Acapulco, Guanajuato, Frontera, Vera Cruz, La Paz (Lower California), Coatzocoalcos, Pachuca, Tuxpan, Nautla, Tlacotalpam, Mazatlan, San Blas, Carmen, Cozumel, Champoton, Perihuete, Las Penas.

They have been received from *British Honduras:* Belize. *Nicaragua:* Blue Fields. *Costa Rica:* Limon and Bocas del Toro, and have also been received from one of the low-lying localities not specifically designated.

From the *Hawaiian Islands* they have been received from Honolulu and Hilo.

They were collected by my assistant, Mr. Marlatt, in *Java* at Batavia, Soekaboemi, Garoet, and at Singapore, *Malay Peninsula.*

From the *Philippine Islands* they have been received from Iligan, *Mindanao;* and from Haganoy and Bulacan, *Luzon.*

In *Cuba* they have been received from Columbia Barracks, Habana; from Guantanamo, Daiquiri, Baracoa, San Antonio de los Banos, Cayamas, "Yaquaramoa," and the Isle of Pines.

From the British West Indies they have been received from Jamaica and Montserrat.

BAHAMA ISLANDS.—Nassau, Spanish Wells, Harbor Island, Current, Tarpon Bay, San Salvador, Long Island, and Government Harbor.

BRAZIL.—Campinas.

No European specimens have been received, but a very interesting locality has turned up in Ismailia, Egypt, whence specimens were received from Dr. W. C. Gorgas, of the United States Army.

From the above it will be seen that although the actual localities which may specifically be designated from the United States are comparatively small in number, and that although combining Theobald's list with our own, the actual localities from other parts of the world are equally sparse, we have still sufficient facts to enable, in my opinion, a sound generalization, both as to probable actual occurrence and as to regions in which the species will readily establish if once introduced. It will be noticed that all of the occurrences within the United States, except Nashville, fall within the limits of what are known as the tropical and lower austral zones. These life zones include practically all of the southern United States which border on the Atlantic Ocean and the Gulf of Mexico, with the exception of those portions of Virginia, North and South Carolina, Georgia, and Alabama, which constitute practically the foothills of the Appalachian chain; in other words, western Virginia and North Carolina, the extreme northwestern corner of South Carolina, the northern part of Georgia, and the extreme northeastern corner of Alabama. Further than this, the lower austral zone includes the western half of Tennessee, the western corner of Kentucky, the extreme southern tip of Illinois, the southeastern corner of Missouri, and all of Arkansas except the northern portion. It also includes the southern portion of Indian Territory, southern Arizona, and some of northern Arizona, and southern strips in Utah, Nevada, and California.

In the greater part of the territory thus indicated, and *where the climate is not too dry*, *Stegomyia fasciata* will, with little doubt upon close search, be found.

2. *The exact limitations of the regions in which, if accidentally introduced, it may reasonably be expected to propagate and to become perfectly established.*

All the rest of the lower austral territory just indicated, and *where the climate is not too dry*, will constitute a region where the yellow-fever mosquito if once introduced will undoubtedly flourish. Even in the drier portions of western Texas, southern New Mexico, southern Arizona, southern California, and southern Nevada, where the climate is exceptionally dry there is a possibility that this species if once introduced will breed in the water supply of ranches, except possibly where the water is impregnated with alkali.

Having made this generalization for the United States, where through the admirable work of Dr. C. Hart Merriam and his Division of Biological Survey of the United States Department of Agriculture,

the subject of the exact limitations of the life zones has been so accurately investigated, and where these zones have been so carefully mapped out, we naturally may follow it with a corresponding generalization for other countries, where the factors which control the distribution of animal and vegetable life are, of course, comparable to those which exist in the United States. We may expect to find this species everywhere in the moist tropical zone, or at all events, when introduced at any point within the low, moist tropics, it may be expected to establish itself. The conditions which control the distribution of life in the so-called lower austral zone will naturally hold equally in corresponding sections elsewhere, and it becomes necessary to formulate as easy a means as possible of ascertaining a region between the parallels of latitude of 38° north and 38° south whose conditions will correspond to those of the lower austral zone in the United States and which will thus admit of the breeding of *Stegomyia fasciata*. It has been determined by Doctor Merriam that the northern limit of the lower austral zone is marked by the isotherm showing a sum of normal positive temperatures of 10,000° C., or 18,000° F. The sum of normal positive temperatures means the sum of normal mean daily temperatures above 6° C., or 43° F. With this rule as a basis we may take, for example, on the borders of the plateau region in Mexico, any given locality or elevation, and may sum up the normal mean daily temperatures above 6° C., or 43° F., and if this sum for the year reaches 10,000° C., or 18,000° F., it is safe to say that the locality is within the limits of the upper austral life zone and that the yellow-fever mosquito will breed there.

The minimum temperature of 6° C., or 43° F., has been estimated as marking the inception of reproductive activity in animals; in other words, the formula which we have just given means that the physiological constant of *Stegomyia fasciata* is approximately 10,000° C. I have, in the opening paragraph under this head, italicized the clause "where the climate is not too dry," for while, as shown by Merriam, the temperature predetermines the possibilities of distribution and fixes the limits beyond which the species can not pass, and defines certain broad transcontinental belts within which certain forms may thrive, *if other conditions permit*, it is by no means the sole factor which determines distribution. Nevertheless, no matter how favorable other conditions may be the species possessing the physiological constant characteristic of this zone can not exist outside. With mosquitoes it is obvious that the factor next in importance to temperature will be moisture, and in the arid Tropics and in the very dry portions of the Lower Austral Zone we will naturally not look for an abundance of mosquitoes, except under artificial conditions brought about by civilization. *Stegomyia fasciata*, however, being a domestic species—that is to say, being practically dependent upon the condi-

tions surrounding human habitations—is less subject to normal conditions of moisture than are the species of the fields and woods.

It is interesting to note that the geographic distribution of the yellow-fever mosquito corresponds rather well with that of the Texas cattle tick (*Boöphilus annulatus*) which is instrumental in the carriage of the Hæmatozoan of Texas fever. That, too, is a creature which seems confined to the tropical and Lower Austral zones.

The southern border of the Lower Austral Zone has not been expressed in a similar formula, but this is unnecessary for the present consideration, since the mosquito breeds readily in both tropical and Lower Austral zones.

The southern limit of the zone in the Southern Hemisphere, corresponding to the northern limits of the Lower Austral Life Zone in the Northern Hemisphere, can probably be calculated by the use of the same formula, and thus in any given locality in the Southern Hemisphere the probable occurrence, or at all events the proper climatic conditions for the existence of *Stegomyia fasciata*, can be ascertained.

I conceive that the facts thus formulated are and will be of great importance in the determination of quarantine measures, and that the careful records which have been urged by the international congress of sanitarians of the American Republics will justify these broad conclusions.

In an article published in the Journal of Tropical Medicine, for August 1, 1903, Mr. Theobald gives some further notes concerning the distribution of other species of *Stegomyia*, in which he shows a slightly greater northern and southern distribution with other forms of the same genus, enlarging the field to from 43° south to 43° north latitude. As yet, however, the agency of only a single species, *Stegomyia fasciata*, in the transfer of yellow fever, has been proved. Let us for the present await experimentation with the other species, of which there are nearly a score, before beginning further attempts at generalizations. In fact, it may very likely be shown that these species have not so close a relationship to *S. fasciata* as to warrant the belief that they may be instrumental in the carriage of this disease. In fact the Australian species, *Stegomyia notoscripta*, laying its eggs, as it does, in "rafts," and not singly, as does *S. fasciata*, may very likely prove to be a distant rather than a close relative of the dangerous form.

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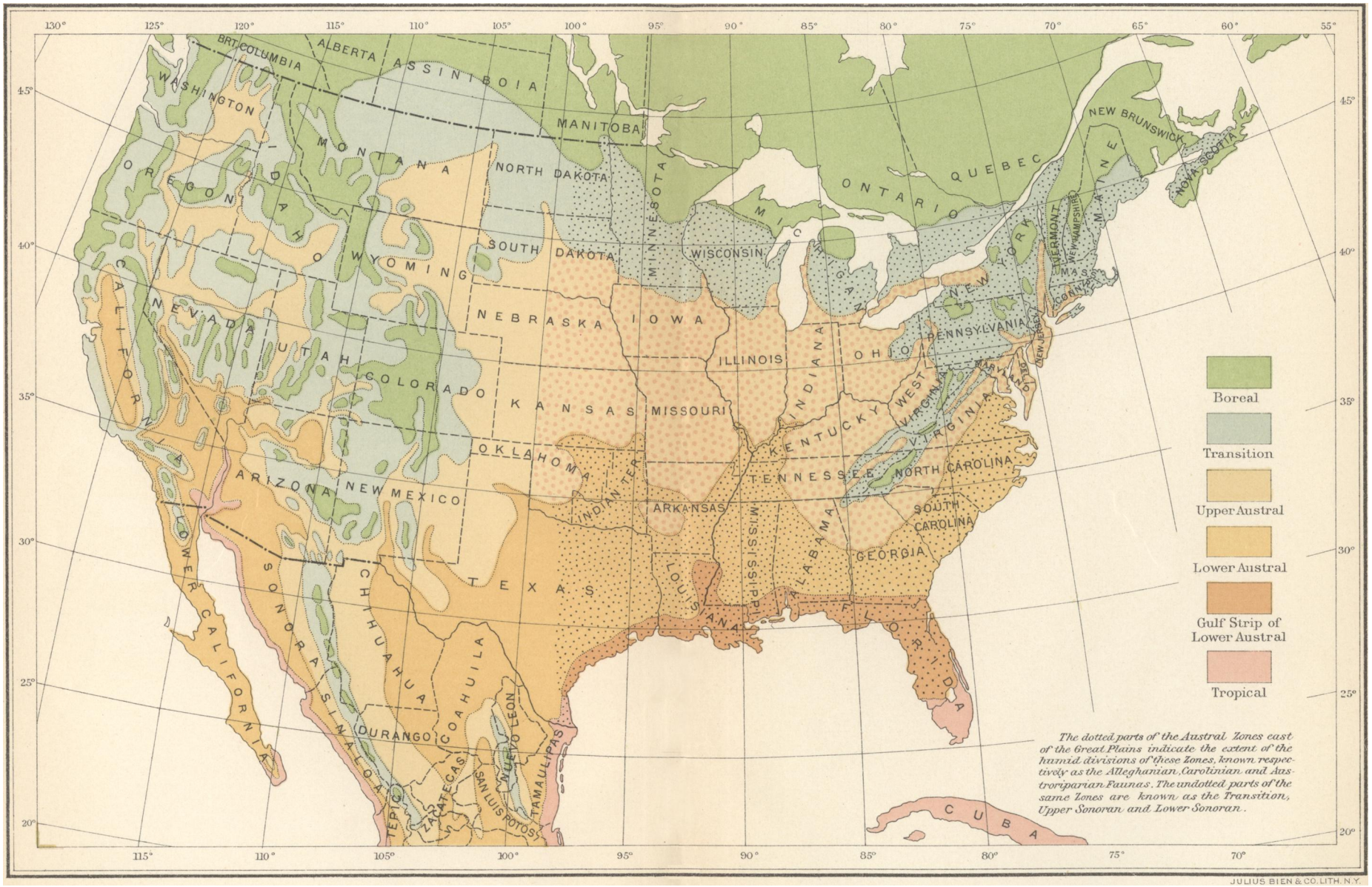

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LIFE ZONES OF THE UNITED STATES

BY

C. HART MERRIAM